Soundscapes to Landscapes (S2L): Monitoring Animal Biodiversity from Space Using Citizen Scientists

Funded by NASA's Citizen Science for Earth Systems Program
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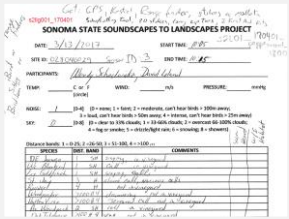
Matthew Clark (PI, Sonoma State Univ.)
Leo Salas (Point Blue Conservation Science)
Scott Goetz (Northern Arizona Univ.)
Pat Burns (Northern Arizona Univ.)
Colin Quinn (Northern Arizona Univ.)
Rose Snyder (Point Blue Conservation Science
David Leland (Audubon California)
Wendy Schackwitz (Audubon California)
Shawn Newsam (UC Merced)
Shrishail Baligar (UC Merced)
Steven Hancock (University of Edinburgh)

Motivation

Biodiversity crisis

Bird populations down 30% in N. America since 1970s



Hard logistics

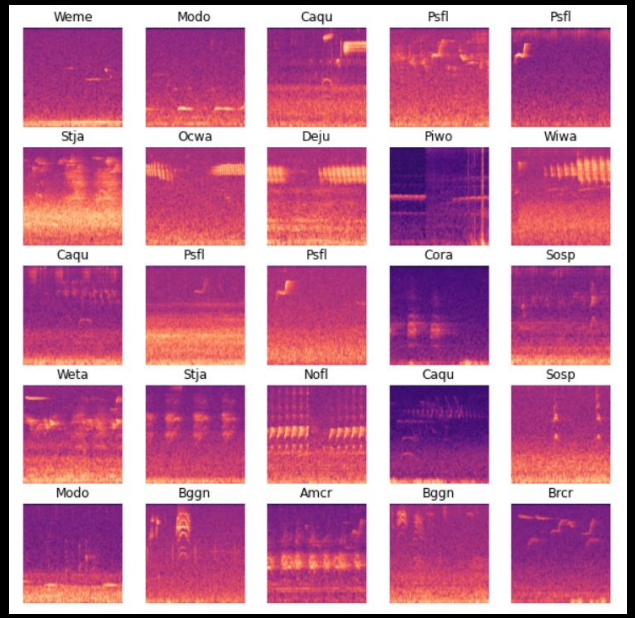
Collecting field data is laborious and site access difficult

Limited expertise

Limited time and increasingly harder to find expertise

Scaling problems

Sampling at regional to global scales cost prohibitive

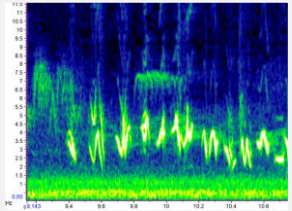


Solution

Turn sound recordings into bird diversity information for monitoring and analysis

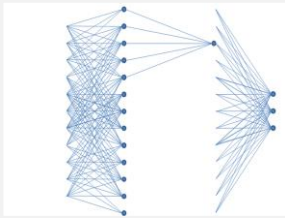
Sound recorders

Low-cost, automated recorders (AudioMoths) capture bird calls and songs



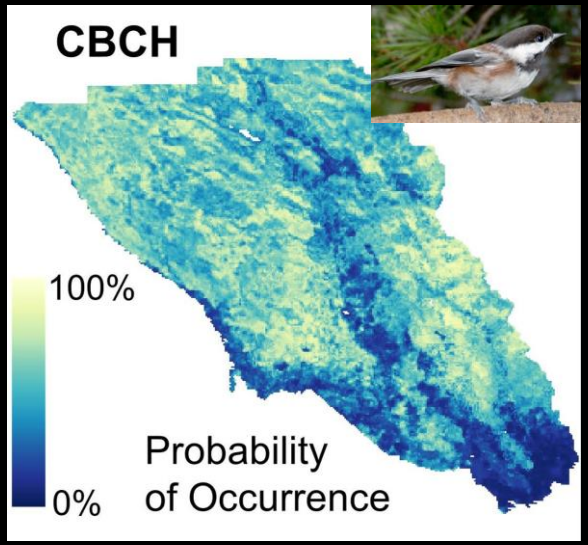
Bioacoustics

Sounds represented as images, called spectrograms



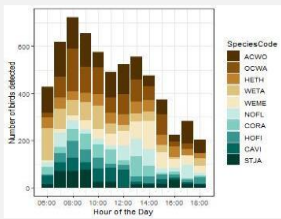
Deep Learning

Convolutional Neural Networks (CNN) detect bird species in spectrograms



Scaling

Use site-level bird presence data and remotely-sensed habitat information for species maps and other products



Bird Detections

Deep learning models give us bird detections at each site

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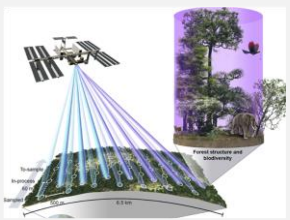

Remote Sensing

GEDI, AVIRIS, Landsat 8/Sentinel-2 provide regional-scale habitat characteristics

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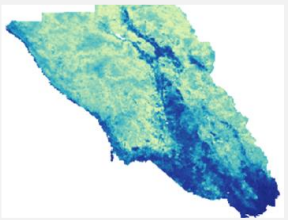
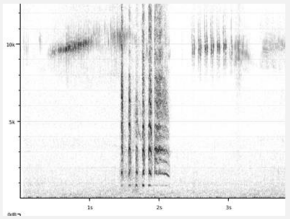
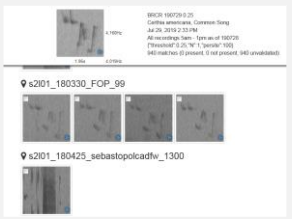


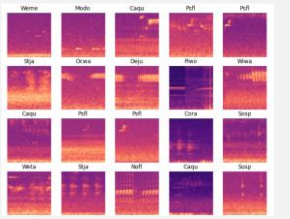
Species Distribution Modeling

Machine learning models help us predict where each species occurs across the entire study area

Powered By Citizen Scientists







Citizen Scientists

Community volunteers, land owners, college students

Field Data

Citizen scientists place audio recorders across Sonoma County, CA during the breeding bird season

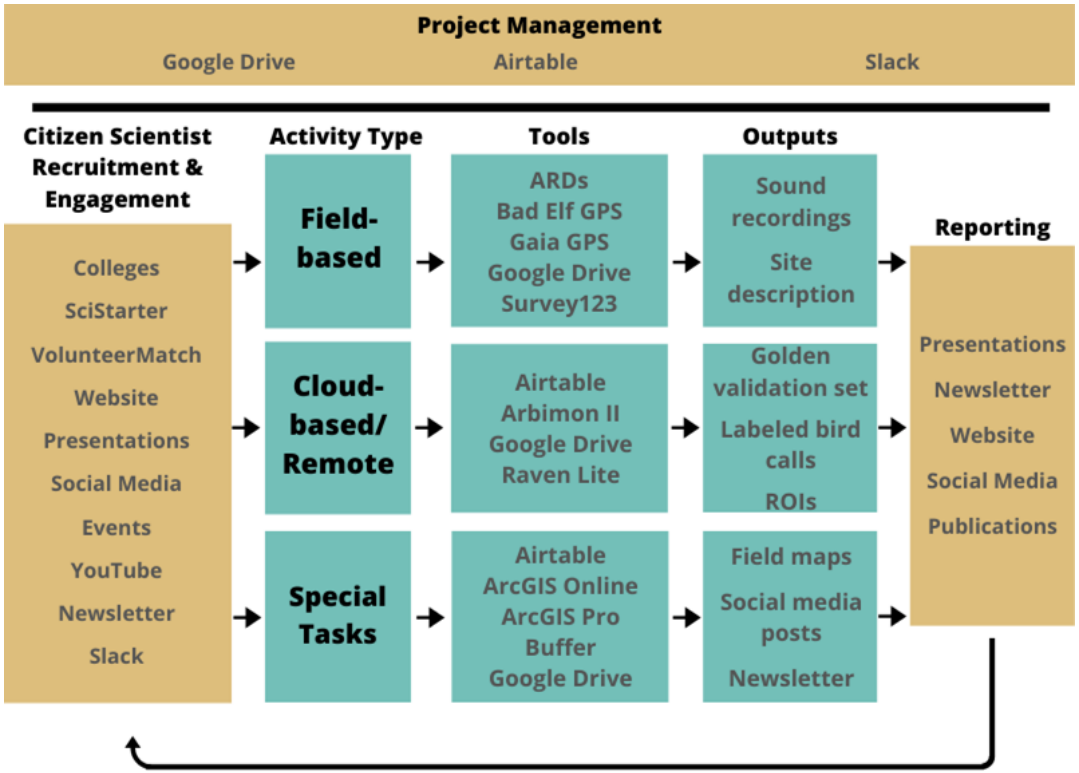
Reference Data Collection ⟺ Deep Learning

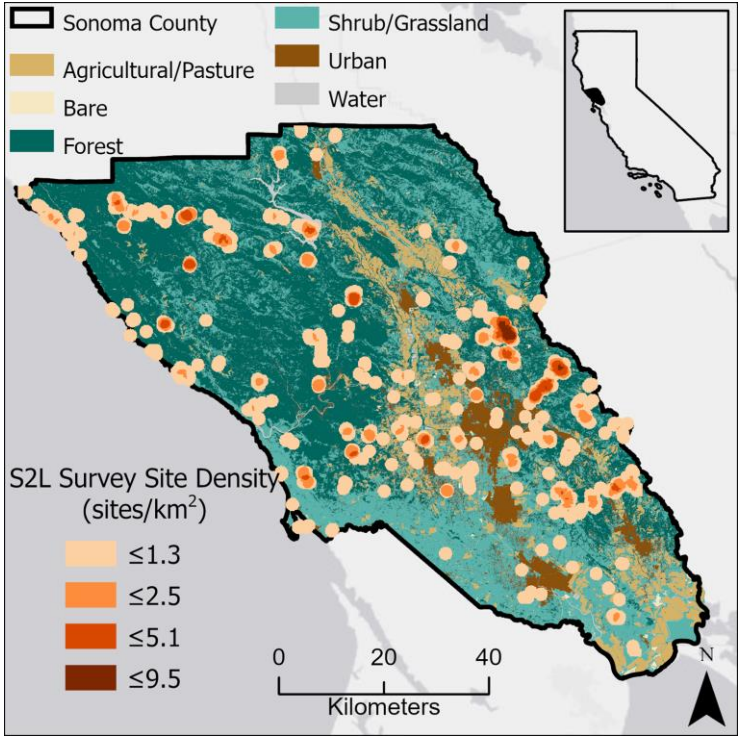
Bird experts identify templates of bird vocalizations in the recordings, and use a pattern-matching tool to find potential matches to these templates

Non-experts review potential matches to identify more clips of the target bird vocalizations (consensus-based voting)

Computer science team uses the collection of clips for each species to train three CNN models; iterative process, linked to reference data collection step

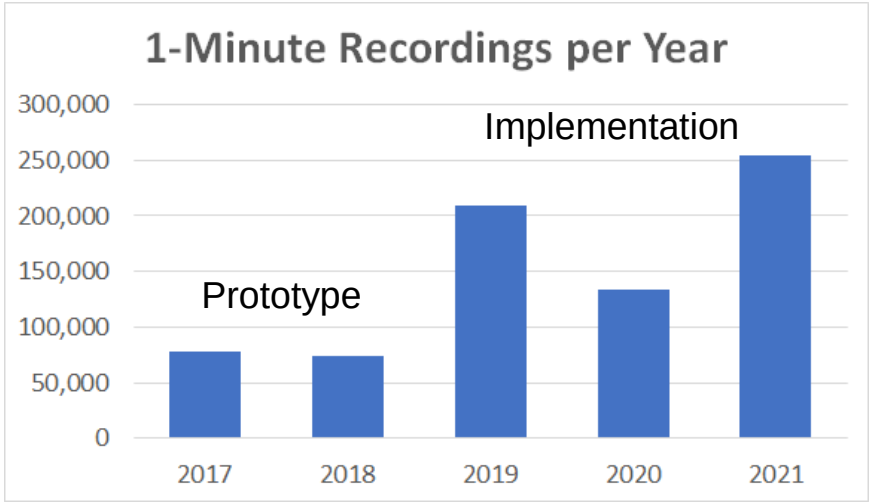
Cloud-based Project Management



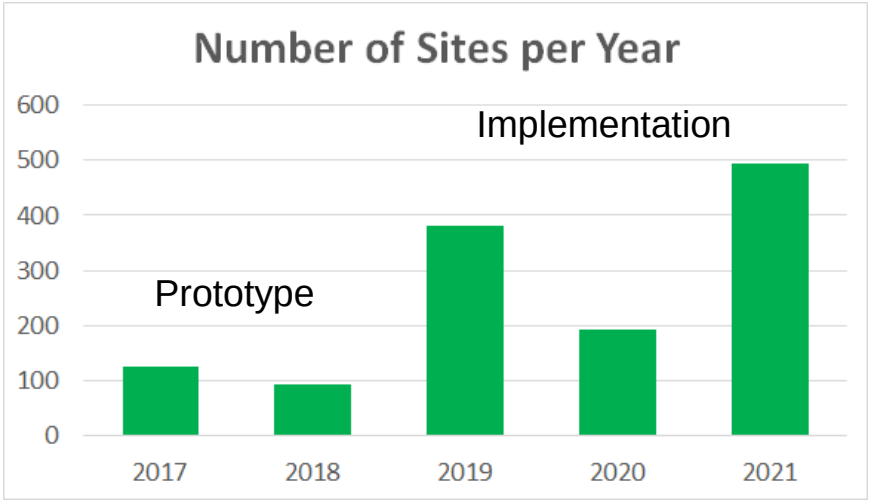


Snyder et al., Citizen Science: Theory and Practice, *in revision*

Breeding Season Acoustic Surveys

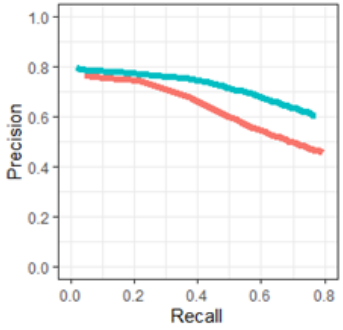


Total = 748,516 minutes



Total = 1,286 sites

Bird-call Classification with CNNs

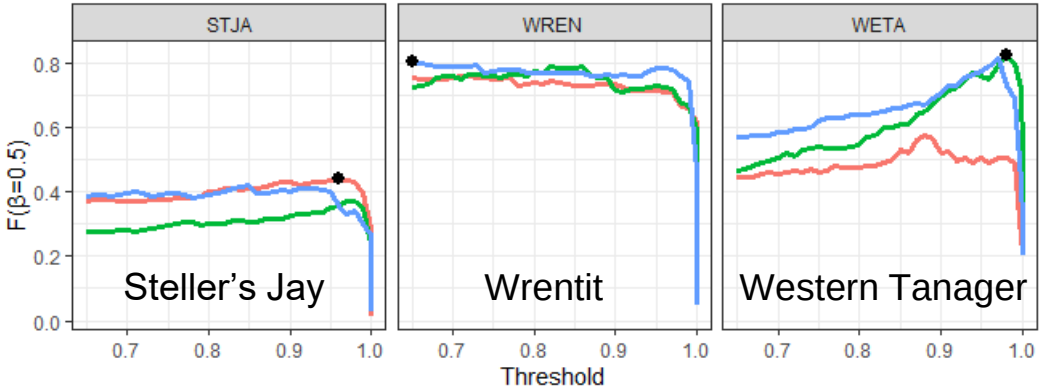


Pre-training

Test source
Not Pre-trained
Pre-trained

Precision vs. Recall for all three CNNs with pre-training using Xeno-Canto sound data relative to not including pre-training. Test data are regions of interest (ROIs) from pattern-matching validations.

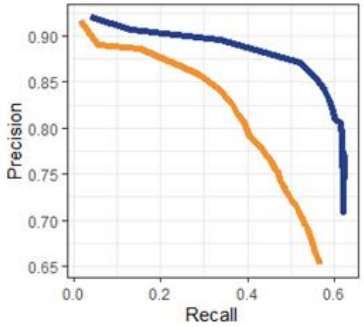
54 species modeled using
3 CNN architectures



Fine-tuning training

Model
MobileNet
Resnet101
Resnet50

Using F-score to determine which of three CNNs to use for a given species. Test data are pattern-matching ROIs.



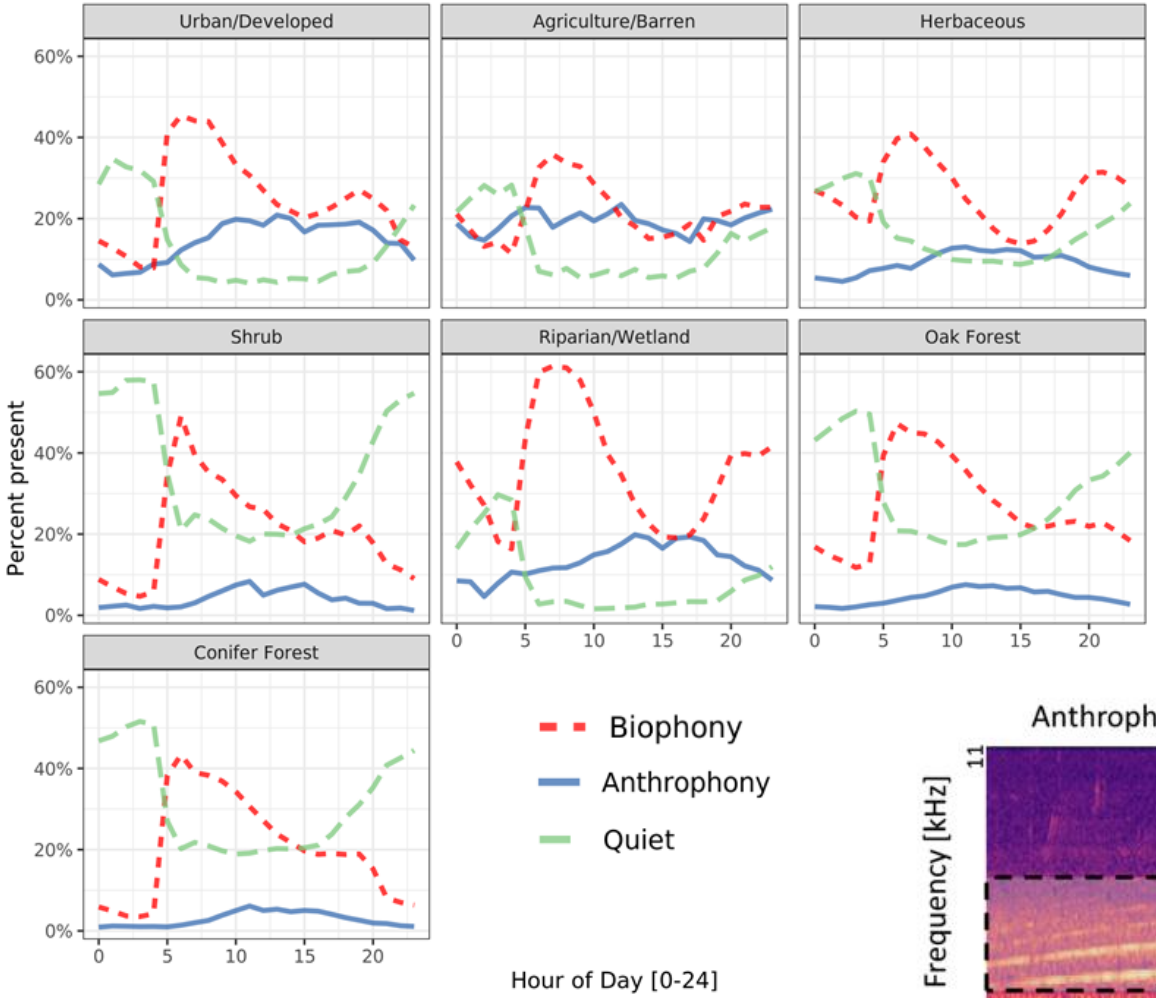
Post-classification correction

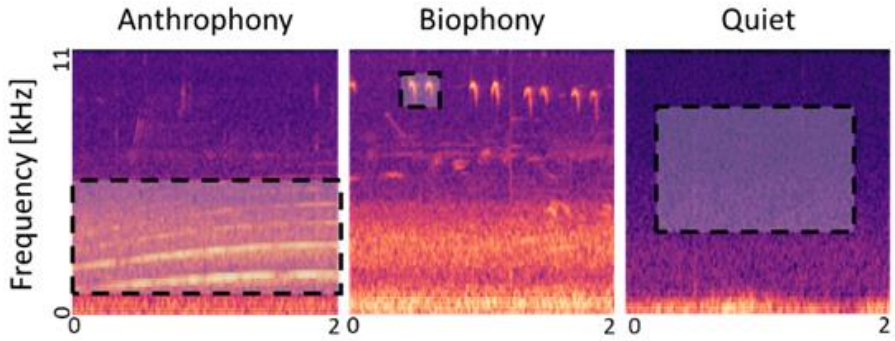
Test source
Corrected golden validations
Uncorrected golden validations

Precision vs. Recall for all CNNs using "golden validation" data (exhaustive assessment of select recordings) with post-classification correction models relative to no correction.

Salas et al., PLOS One, *in prep.*

CNN for Anthrophony, Biophony, Geophony & Quiet (ABGQ)





Quinn et al., Eco. Indicators, *in prep.*

Landowner Property Reports

Soundscapes to Landscapes
Property Report

The Soundscapes to Landscapes (S2L) project is pleased to share with you results obtained from the sound recordings taken from your property. Here we present a list of species detected on your property, as well as several graphics summarizing the bird diversity found on your property. Please note that we monitored for a select 54 bird species, so if you are well-acquainted with the birds on your property, you may notice that some of the birds you have identified on your property are missing from our list. The list of species we targeted can be found on our website in the "For Landowners and Land Managers" section of the following page: https://soundscapes2landscapes.org/volunteers/materials.

If you have any follow-up questions regarding this report, please contact the S2L Project Coordinator Rose Snyder at rsnyder@pointblue.org.

Property Name: Pepperwood Preserve

Total Number of Recording Minutes: 146821

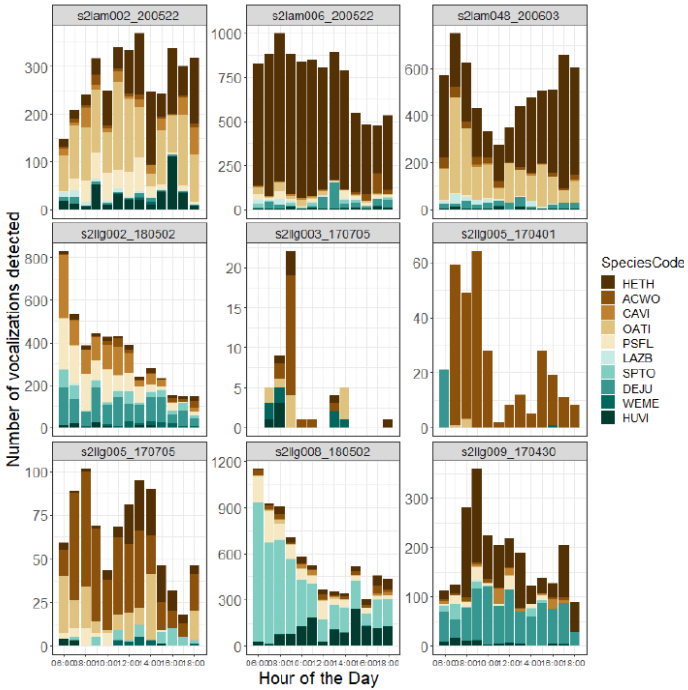
Link to Annotated Recording: https://youtu.be/LvjYIxBW09A

Note: Follow the above URL to be directed to a hand-selected one-minute recording from your property with the bird calls labeled by one of S2L's expert citizen scientist birders.

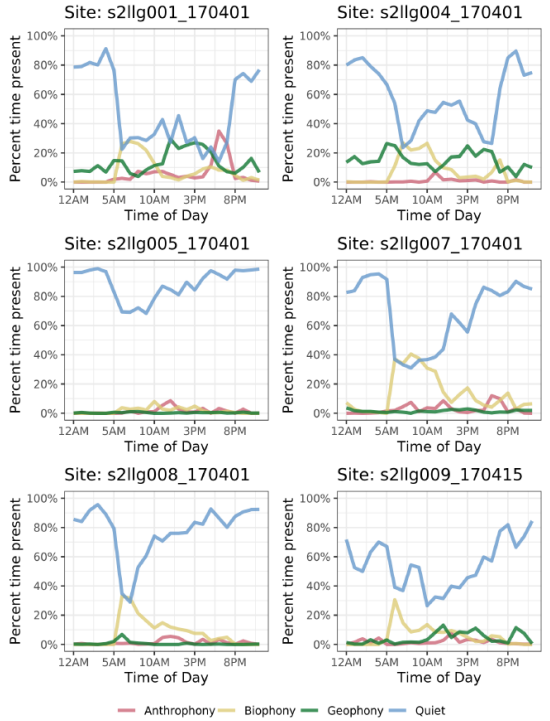
Dates Surveyed:

Deployment Date	Retrieval Date
April 01, 2017	April 06, 2017
April 30, 2017	May 04, 2017
June 13, 2017	June 27, 2017
June 16, 2017	June 20, 2017
June 16, 2017	June 27, 2017
June 20, 2017	June 23, 2017
June 27, 2017	July 01, 2017
June 27, 2017	July 08, 2017
July 01, 2017	July 05, 2017
July 05, 2017	July 08, 2017
July 08, 2017	July 28, 2017
July 28, 2017	August 16, 2017
August 04, 2017	August 23, 2017
April 14, 2018	April 18, 2018
May 02, 2018	May 09, 2018
June 24, 2018	June 30, 2018

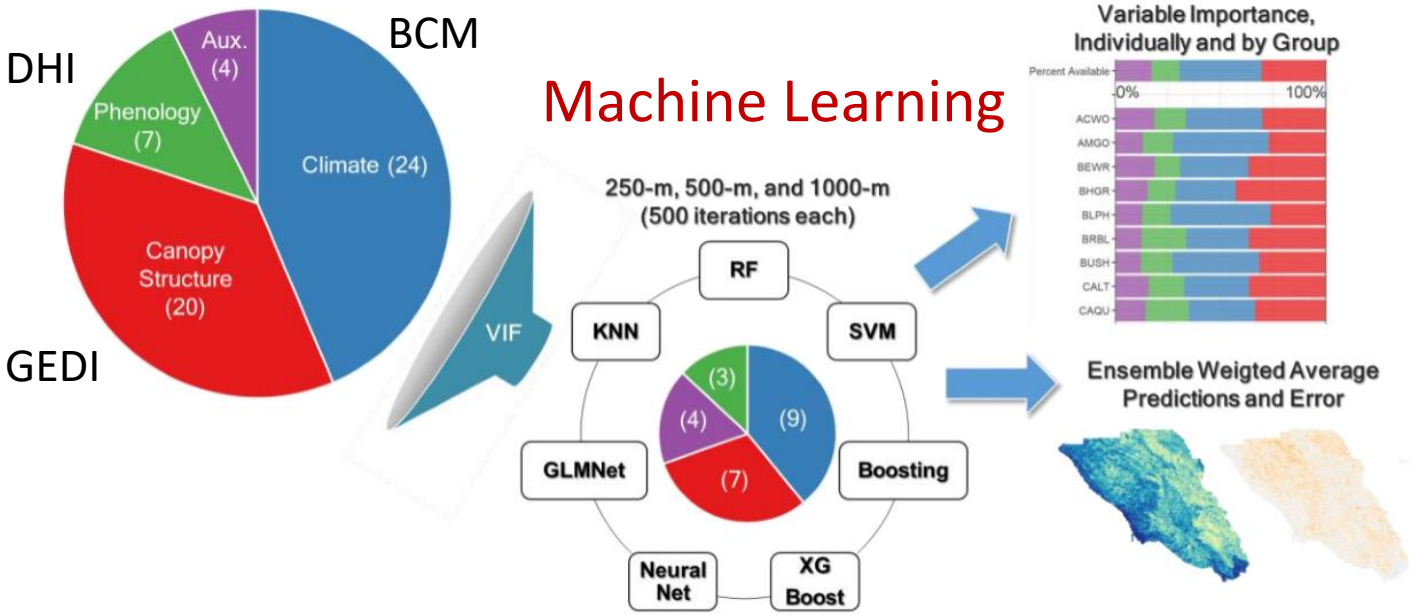
Species detections by site



ABGQ detections by site



Species Distribution Modeling

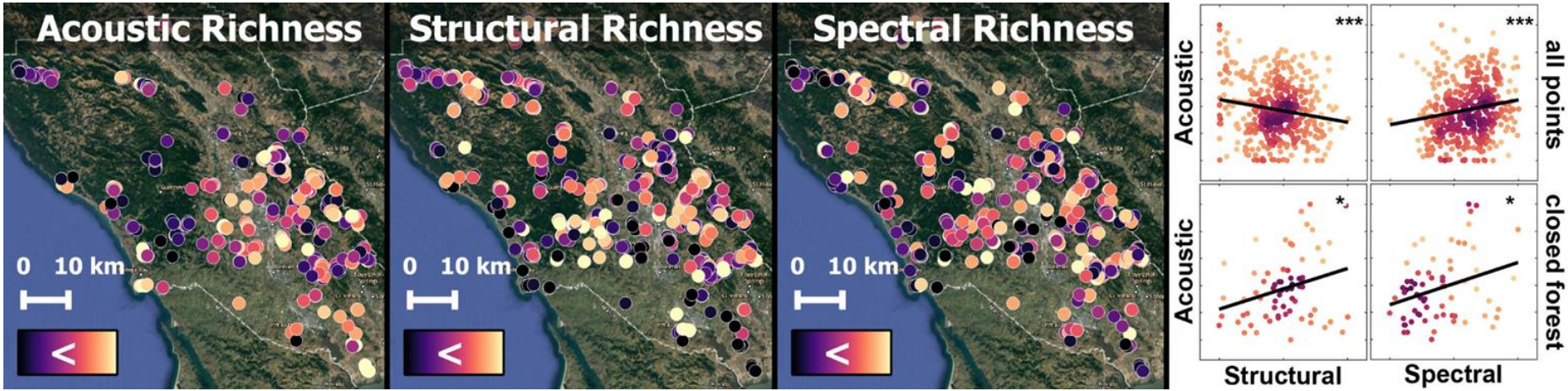


Burns et al., ERL 2020

- Our previous work used existing Point Blue, Breeding Bird Survey (BBS), & eBird data, 25 different species
- Update will include S2L acoustics-based bird species data with AVIRIS (chemistry), airborne lidar (structure), and Landsat 8/Sentinel-2 (phenology)

Acoustic-Structural-Spectral Relationships

CNN features **Airborne Lidar** **AVIRIS > EnMap**



Fabian Schneider (JPL)
Antonio Ferraz (JPL/UCLA)
Leo Salas (Point Blue)
Matthew Clark (Sonoma State)
Akpona Okujeni (Humboldt-Universität zu Berlin)

Connecting bioacoustics and remote sensing to study habitat-animal diversity relationships in Sonoma County, CA

AGU 2021, Session B13A: Advances in Remote Sensing for Monitoring Biodiversity Change: Integrating Data and Models Across Scales and Technologies III

www.soundscapes2landscapes.org